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Renewable energy consumption–economic growth nexus in Turkey

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ABSTRACT

This paper examines the renewable energy consumption–economic growth causality nexus in Turkey. Studies in the literature can be grouped as country-specific and multi-country studies. The results of these studies are inconsistent, and there is no agreement on the existence or the direction of causality between renewable energy consumption and economic growth. The results of this country-specific study support conservation hypothesis. The results of empirical tests from ARDL approach show that renewable energy consumption has a negative impact on economic growth, and the ones of Toda–Yamamoto causality tests show that there is a unidirectional causality running from economic growth to renewable energy consumption.

Contents

1. Introduction

Environmental consequences of global warming and greenhouse gas emissions increase the concerns of the consumption of fossil fuels; therefore, renewable energy sources have emerged as an important component of world energy consumption. Most important features of renewable energy sources are reducing carbon dioxide emissions and assisting to protect the environment. Theoretically, fossil fuels are considered to be able to renew themselves for a very long period of time, but they are in danger of complete extinction in the near future.

According to International Energy Outlook [1], a rapid growth took place in the field of renewable energy around the world; biofuel production in the world has increased 13.8%, and wind energy consumption has increased 15.5% in 2010. Although Turkey has a rich variety and potential of renewable sources of energy, it unfortunately uses less than 1% of its renewable energy potential. It has 8% of the geothermal energy potential and a high amount of hydro-energy and wind energy potential. It also gets a large amount of solar energy due to its geographical location. Furthermore, Turkey′s energy market is nearly 70% of primary energy consumption, and 60% of the electricity consumption is dependent on import, so consuming local and/or renewable energy sources is very important.

It has generally been realized that both the production and consumption of renewable energy play a vital role for economy and environment. Also, the causal relationship between renewable energy consumption and economic growth is vital for environmental and energy policies. In the literature, the causal relationship between renewable energy consumption and economic growth has been investigated in a number of studies. These studies have focused on different countries, periods, variables and used different econometric methodologies. However, there is no consensus on empirical results of these studies, which show different causality directions. On the other hand, the kind of causal relationship is vital for the policy implications [2–6].

Directions of the causal relationship between renewable energy consumption and economic growth should be categorized into

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four hypotheses, each of which has important implications for energy policy [7]. *The growth hypothesis* suggests that unidirectional causality runs from energy consumption to economic growth. It implies that increase in energy consumption have a positive impact on economic growth. Therefore, energy consumption has a vital role in economic growth in production process. If there is a unidirectional causality from economic growth to energy consumption, it is called *conservation hypothesis.* This hypothesis supports that the reduction in energy consumption will have little/no effect on economic growth. Also, it is supported that an increase in real GDP causes an increase in energy consumption. *The feedback hypothesis* argues bidirectional causality between energy consumption and economic growth. This relationship implies that there is a joint effect between energy consumption and economic growth. In other words, energy conservation has negative effect on economic growth, and decreases in GDP have negative impact on energy consumption. No causality between energy consumption and economic growth is referred to as *neutrality hypothesis.* Under the neutrality hypothesis, energy consumption is not correlated with GDP, which means that the increase or decrease in energy consumption has no effect on economic growth and vice versa.

The aim of this study is to examine the relationship between renewable energy consumption, capital, labour, and economic growth for Turkey for the period of 1990–2010 using autoregressive distributed lag (ARDL) approach of Pesaran et al. [8] and Toda and Yamamoto [9] causality tests. This study extends the existing literature specifically on the causal relationship between renewable energy consumption and economic growth; in the literature, there is no study which has investigated this relationship in Turkey. The rest of the paper is organized as follows: Section 2 provides the previous literature regarding the causality between renewable energy consumption and economic growth for both country-specific and multi-country studies. Section 3 presents the data, method, and results. Section 4 provides conclusions.

2. Literature review

Several studies in the literature have examined the relationship between renewable energy consumption and economic growth. The results of these studies have no consensus because of using different data, period, and methodological approach. Therefore, some studies have found unidirectional causality running from renewable energy consumption to economic growth, and running from economic growth to renewable energy consumption. On the other hand, others have found no causality and/or bidirectional causality between renewable energy consumption and economic growth. The chronological list of the empirical literature on the causality between renewable energy consumption and economic growth is displayed in Table 1, presenting the author, period, methodology, and empirical results.

These studies show that the results regarding the causal relationship between renewable energy consumption and economic growth are conflicting and mixed across different countries as shown in Table 1.

Sarı et al. [10] examine the relationship between renewable energy consumption and industrial output with ARDL approach in the US over the period of 1969–2009, and find that industrial output has a positive impact on hydroelectric, waste, and wind energy consumption and a negative impact on solar energy consumption. For the US, Payne [11] uses Toda–Yamamoto causality tests to examine the relationship between renewable and non-renewable energy consumption and economic growth for the period of 1949–2006, and the results show no causality between renewable energy consumption and economic growth.

By using Granger causality test, Menyah and Wolde-Rufael [12] explore the causal relationship among renewable and nuclear energy consumption and economic growth for the US over the period of 1960–2007. The results suggest no causality between renewable energy and CO_2 emissions, but unidirectional causality from nuclear energy consumption to CO_2 emissions. Bowden and Payne [13] use Toda-Yamamoto long-run causality test for US from 1949 to 2006 to examine the causality between sectorial non-renewable/renewable energy consumption and real GDP. The test results suggest neutrality hypothesis for commercial and industrial renewable energy consumption and real GDP nexus, while they suggest feedback hypothesis for commercial and residential non-renewable energy consumption and real GDP nexus. Also, there is a unidirectional causality running from residential renewable energy consumption to GDP.

Payne [14] examines the causal relationship between biomass energy consumption and real GDP by using the Toda–Yamamoto causality tests for Granger causality within a multivariate framework for the US for the period of 1949–2007. The empirical tests show unidirectional causality running from biomass energy consumption to real GDP.

For the period of 1994–2003 in 18 emerging countries, Sadorsky [15] uses panel error correction model to test the relationship between economic growth and renewable energy consumption, and the results support conservation hypothesis. Empirical results show that real income increases have positive and statistically significant impact on per capita renewable energy consumption. For G7 countries, Sadorsky [16] indicates that increase in oil price have small and negative impact on renewable energy consumption.

For 13 Eurasia countries, Apergis and Payne [17] examine the causal relationship between renewable energy consumption and economic growth for the period of 1992–2007 in both the short-run and long-run, by using Granger causality tests. Empirical results support the feedback hypothesis. In addition, the findings of Apergis and Payne [18] support the feedback hypothesis for a panel of twenty OECD countries over the period of 1985–2005.

Apergis et al. [5] use panel error correction model for a group of 19 developed and developing countries for the period of 1984–2007 to explore the causal relationship among nuclear energy consumption, renewable energy consumption, and economic growth. For the long-run, the empirical results show negative association between nuclear energy consumption and emissions, but a positive relationship between emissions and renewable energy consumption. In the short-run, Granger causality test results indicate that nuclear energy consumption is important for reducing CO_2 emissions, whereas renewable energy consumption is not. Apergis and Payne [6] use the same method for a panel of six Central American countries to examine the causal relationship between renewable energy consumption and economic growth for the period of 1980–2006. In the short and the long-run, the results suggest feedback hypothesis.

For 27 European countries, Menegaki [19] uses multivariate panel framework random effect model for the period of 1997–2007. Empirical test results suggest no causality between renewable energy consumption and GDP.

Salim and Rafiq [20] use fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS) and Granger causality tests to determine the relationship between renewable energy consumption and GDP in Brazil, China, India, Indonesia, Philippines, and Turkey for the period of 1980–2006. The results suggest that renewable energy consumption is significantly determined by income in the long-run. In both the short- and long-run, Apergis and Payne [21] suggest feedback hypothesis for 80 countries for the period of 1990–2007 by using panel error correction model to test the relationship among renewable and non-renewable energy consumption and economic growth.

Table 1
Summary of literature on REC-EG nexus.

Author(s)	Country(ies) and period	Methodology	Variables	Conclusion(s)
Sari et al. [10]	U.S.A (1969–1999)	ARDL	REC; IO	IO has a positive impact on hydroelectric, waste and wind EC and has a negative impact on solar EC.
Payne [11]	U.S.A. (1949–2006)	Toda-Yamamoto causality tests	EC; REC; EG	Neutrality hypothesis
Menyah and Wolde-Rufael [12]	U.S.A. (1960–2007)	Granger causality test	REC; EG	Conservation hypothesis
Bowden and Payne [13]	U.S.A. (1949–2006)	Toda-Yamamoto long-run causality test	Sectorial EC; REC; EG	No causality among commercial and industrial REC and EG; bidirectional causality among commercial and residential EC and EG; Unidirectional causality from residential REC to EG.
Payne [14]	U.S.A. (1949–2007)	Toda-Yamamoto causality tests	Biomass EC; EG	Unidirectional causality from biomass EC to EG
Sadorsky [15]	18 emerging countries (1994–2003)	Bivariate panel error correction model	REC; EG	Increases in RI have positive and significant impact on per capita REC.
Sadorsky [16]	G-7 Countries (1980–2005)	Panel cointegration	REC; CO_2; OP; EG	Increases in OP have small and negative impact on REC.
Apergis and Payne [17]	13 Eurasia countries (1992–2007)	Error correction model (Granger causality)	REC-EG	Feedback hypothesis
Apergis and Payne [18]	20 OECD countries (1985–2005)	Granger-causality	REC-EG	Feedback hypothesis in both the short- and long-run
Apergis et al. [5]	19 developed and developing countries (1984–2007)	Panel error correction model; Panel Granger causality test	NEC; REC; CO_2; EG	Negative relationship between NEC and CO_2, positive relationship between CO_2 and REC, in the short-run; NEC reduce CO_2 but REC does not.
Apergis and Payne [6]	6 Central American countries (1980–2006)	Panel error correction model	REC; EG	Feedback hypothesis in both the short- and long-run
Menegaki [19]	27 European countries n (1997–2007)	Multivariate panel framework	REC; EG	Neutrality hypothesis
Salim and Rafiq [20]	Brazil, China, India, Indonesia, Philippines and Turkey (1980–2006)	Granger causality	REC; EG	In the long-run, REC is significantly determined by EG in Brazil, China, India, Indonesia, Philippines and Turkey. In the short run bidirectional causality between REC and EG.
Apergis and Payne [21]	80 countries (1990–2007)	Panel error correction model	EC; REC; EG	Feedback hypothesis in both the short- and long-run
Tugcu et al. [22]	G-7 Countries (1980–2009)	Hatemi-J causality tests	REC; EG	Neutrality hypothesis for France, Italy, Canada and U.S.A, Feedback hypothesis for England and Japan Conservation hypothesis for Germany
Yildirim et al. [23]	U.S.A. (1949–2010)	Toda-Yamamoto and Hatemi-J causality tests	REC; EG	Neutrality hypothesis, Growth hypothesis (causality from biomass-waste-derived energy consumption to economic growth)
Al-mulali et al. [7]	108 countries (Low income countries, Lower middle income countries, upper middle income and high income countries) (1980–2009)	Fully modified OLS tests	REC; EG	79% of the countries feedback hypothesis, 19% of the countries neutrality hypothesis, 2% of the countries conservation and growth hypothesis.
Pao and Fu [24]	Brazil (1980–2010)	Error correction model	EC; REC; EG	Feedback Hypothesis (EG and REC), Conservation hypothesis (EG and EC)

Note: The abbreviations are as follows: Energy Consumption (EC), Renewable Energy Consumption (REC), Electricity Consumption (ELC), Nuclear Energy Consumption (NEC), CO_2 Emissions (CO_2), Real GDP (EG), Real Income (RI), Industrial Output (IO), Real Oil Price (OP), Oil Consumption (OC), Autoregressive Distribution Lag (ARDL), Dynamic Vector Error Correction model (VEC).

Tugcu et al. [22] investigate the long-run and causal relationships between renewable energy consumption and economic growth by using Hatemi-J causality tests for G7 countries for the 1980–2009 period. The estimates show no causality for France, Italy, Canada, and the USA, bidirectional causality for England and Japan, and unidirectional causality from EG to REC for Germany. Yildirim et al. [23] apply Toda–Yamamoto and Hatemi-J causality test for the USA for the period of 1949–2010. Empirical model results reveal only one causal relationship from biomass-waste-derived energy consumption to real GDP, while there is no causal relationship between real GDP and other renewable energy kinds (total renewable energy consumption, geothermal energy consumption, hydro-electric energy consumption, biomass energy consumption, or biomass-wood-derived energy consumption).

Al-mulali et al. [7] use fully modified OLS tests to investigate the bidirectional relationship in the long-run between the renewable energy consumption of high-income, upper-middle-income, lower-middle-income, and high-income countries and GDP growth over the

period of 1980–2009. The results represent the feedback hypothesis for 79% of the countries, neutrality hypothesis for 19% of the countries, and conservation and growth hypotheses for 2% of the countries. Moreover, Pao and Fu [24] employed vector error correction model to test the relationship of renewable and non-renewable energy consumption and economic growth; empirical results suggest feedback hypothesis for the relationship between GDP and renewable energy consumption and conservation hypothesis for the relationship between GDP and energy consumption.

This study explores the relationship between renewable energy consumption and economic growth for Turkey by using Toda and Yamamoto [9] causality tests.

3. Data—methodology and results

Annual data from 1990 to 2010 were obtained from the World Data Bank Development Indicators for Turkey. The econometric framework includes GDP (Y) in billions of constant 2000 US $, gross fixed capital formation (K) in billions of constant 2000 US $, total labour force ($L$) in millions, and combustible renewables and waste % of total energy (RE) defined in thousands of metric tons. In this study, Pesaran et al. [8] ARDL approach tests will be employed for co-integration and the Toda and Yamamoto tests [9] will be used for the causality for the period of 1990–2010.

The ARDL bounds test approach is more preferable than the other conventional co-integration tests because several important advantages of ARDL bounds test approach over other tests have been shown by Monte Carlo evidence. The ARDL approach efficiently adapts for possible endogeneity of explanatory variables, and the estimations show desirable small example properties. Another significant advantage of the ARDL approaches is that they can avoid the problems of unit root pre-testing as the test can be used regardless of whether the series are $I(0)$ or $I(1)$. In this way, both the short- and the long-run relationship can be estimated together.

In unit root analysis, Augmented Dickey–Fuller test (ADF–WS) is employed to have good size and power properties. Leybourne et al. [25] have also recently explained that weighted symmetric Augmented Dickey–Fuller test (ADF–WS) has good size and power properties when it is compared with the other unit root tests. Therefore, it needs much shorter sample sizes than conventional unit root tests to attain the same statistical power. To overcome the low power problems associated with conventional unit root tests, especially in small samples, we therefore choose the ADF–WS test of Park and Fuller [26] (Table 2).

This study employed ARDL bounds testing approach of co-integration which was developed by Pesaran and Shin [27,28] and Brown et al. [29] to investigate the causality between renewable energy consumption and GDP for Turkey. An advantage of the ARDL co-integration approach over other co-integration methods is that it can be used regardless of whether the regressors are $I(1)$ and/or $I(0)$. So, it can be applied irrespective of whether underlying regressors are purely $I(0)$, purely $I(1)$, or mutually co-integrated, and thus, there is no need for unit root pre-testing. Another advantage is that it is a statistically more significant approach to determine the co-integration relation in small samples. In addition, the ARDL approach tolerates different optimal lags the variables may have, while it is impossible with classical co-integration procedures. A final advantage is that the ARDL approach employs a single reduced form equation although the classical co-integration models estimate the long-run relationship within a context of system equation.

For co-integration, the ARDL model involves two steps to estimate long-run relationship [8]. The first is to examine the existence of long-run relationship among all variables in the equation under estimation. For the standard log-linear functional specification of long-run relationship between renewable energy consumption and real GDP, the ARDL approach can be shown as

$$\Delta \mathrm{GDP}_t = \alpha_1 + \sum_{i=1}^{p1} \phi_{1i} \Delta \mathrm{GDP}_{t-i} + \sum_{j=0}^{q1} \beta_{1j} \Delta \mathrm{REC}_{t-j} + \delta_1 \mathrm{GDP}_{t-1} + \delta_2 \mathrm{REC}_{t-1} + \varepsilon_{1t} \tag{1}$$

where ε_{1t} is white noise term and Δ is the first difference operator. The ARDL approach estimates $(p+1)^k$ number of regressions in order to get the optimal lag length for each variable, where p is the maximum number of lags to be used, and k is the number of variables in the equality. An appropriate lag selection is based on a criterion such as Schwarz Bayesian Criterion (SBC) (Table 3).

The bounds testing procedure is based on the joint Wald statistic or F-statistic that tested the null hypothesis of no co-integration, $H_0 : \delta_r = 0$, against the alternative of, $H_0 : \delta_r = 0$, $r=1$, 2. Pesaran et al. [8] report two sets of critical values that provide critical value bounds for all categorizations of the regressors into only $I(1)$, only $I(0)$, or mutually co-integrated.

If the computed F-statistics lie above the higher critical bounds, the null of no co-integration is rejected regardless of whether the series are $I(0)$ or $I(1)$, indicating co-integration. If the computed F-statistics fall below the lower critical value, we cannot reject the null hypothesis of no co-integration. Finally, if the computed test statistics lie between the bounds, a conclusive inference cannot be made without knowing the order of integration of the underlying regressors.

Table 3
Results for co-integration analysis.

F-stat	7.0383	
ECM (−1)	−.73364 (0.000)	co integration

Note: ARDL(1,0,0,0) selected based on Schwarz Bayesian Criterion.

Table 2
ADF–WS unit root tests.

Variables	Level		1st differences	
	Without trend	With trend	Without trend	With trend
RE	−.38676 (1)	−1.6278 (0)	−2.5077[a] (0)	−5.2938[a] (0)
Real GDP	.15207 (1)	−2.6761 (1)	−3.3464[a] (0)	−3.1613 (1)
Capital	.13292 (0)	−2.6764 (1)	−3.7687 [a] (1)	−3.9066[a] (1)
Labour	.50021 (1)	−1.9071 (1)	−2.3031[a] (1)	−4.0397[a] (1)
	−2.2729 (0)	−3.4485 (0)	−2.1404 (0)	−3.6503 (0)
Critical Values (CV)	−2.3603 (1)	−3.6575 (1)	−2.2504 (1)	−3.7332 (1)

Note: CV=95% simulated critical value using 18 obs. and 1000 replications.

[a] Illustrates at 1% statistical significance.

If there is a co-integration between variables, the second step is to estimate the following long-run and short-run models that are denoted in the next equalities: where ψ is the coefficient of error correction term.

$$\mathrm{GDP}_t = \alpha_2 + \sum_{i=1}^{p2} \varnothing_{2i}\mathrm{GDP}_{t-i} + \sum_{j=0}^{q2} \beta_{2j}\mathrm{REC}_{t-j} + \varepsilon_{2t} \tag{2}$$

$$\Delta\mathrm{GDP}_t = \alpha_3 + \sum_{i=1}^{p3} \varnothing_{3i}\mathrm{GDP}_{t-i} + \sum_{j=0}^{q3} \beta_{3j}\mathrm{REC}_{t-j} + \psi\mathrm{RECT}_{t-1} + \varepsilon_{3t} \tag{3}$$

We examine the relationship between renewable energy consumption and economic growth with the ARDL approach in Turkey over the period of 1990–2010, and in Table 3 the results show that significant negative error–correction parameters also confirm the existence of co-integration relationship for those samples (Table 4).

Accordingly, estimated coefficients indicate that renewable energy consumption has negative impacts on economic growth for Turkey with statistical significance at 1% level. In accordance with the literature, capital and labour have a positive effect on GDP, but RE is adversely affected. Also, if RE increases 1%, GDP decreases 0.30% (Table 5).

It is displayed that none of the estimated models (even 10% significance level) have serial correlation, heteroscedasticity, non-normality, or functional form. As well as the diagnostic tests, stability of the co-integration parameters was confirmed by the CUSUM and CUSUMSQ. These tests for parameter stability based on the recursive regression residuals were developed by Pesaran and Shin [28]. According to the results, all of the models have stable parameters over time.

For causality test, we applied Toda and Yamamoto tests [9] which are available whether the series is $I(0)$, $I(1)$, or $I(2)$, non-cointegrated, or co-integrated of any arbitrary order. To take on the Toda and Yamamoto non-causality test [9], for VAR (3), ($k=2$ and $d_{\max}=1$), we estimate the next system equations as

$$\begin{bmatrix} \ln Y_t \\ \ln RE_t \\ \ln K_t \\ \ln L_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} \ln Y_{t-1} \\ \ln RE_{t-1} \\ \ln K_{t-1} \\ \ln L_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} \ln Y_{t-2} \\ \ln RE_{t-2} \\ \ln K_{t-2} \\ \ln L_{t-2} \end{bmatrix} + A_3 \begin{bmatrix} \ln Y_{t-3} \\ \ln RE_{t-3} \\ \ln K_{t-3} \\ \ln L_{t-3} \end{bmatrix} + \begin{bmatrix} \varepsilon\ln Y_t \\ \varepsilon\ln RE_t \\ \varepsilon\ln K_t \\ \varepsilon\ln L_t \end{bmatrix} \tag{4}$$

Table 4
Results for long-run coefficients.

Dependent variable is GDP	Constant	.26636 (0.00)
	RE	−.30051 (0.00)
	Capital	.19006 (0.00)
	Labour	.022477 (0.00)

Table 5
Results for diagnostics.

Dependent variable is GDP	*Tests*	*LM Version*
	Serial correlation[a]	.043679[.834]
	Heteroscedasticity[b]	.47319[.492]
	Normality[c]	.62110[.733]
	Functional form[d]	1.1156[.291]
	CUSUM	Stable
	CUSUMQ	Stable

Note:

[a] The Breusch–Godfrey LM test statistic for no serial correlation.
[b] The White's test statistic for homoscedasticity.
[c] The Jarque–Bera statistic for normality.
[d] The Ramsey's Reset test statistic for regression specification error.

In Eq. (4) A_1–A_3 are four 4 by 4 matrices of coefficients with A_0 being the 4 by 1 identity matrix and ε are the disturbance terms with zero mean and constant variance. Renewable energy consumption ($\ln RE_t$) does not Granger cause economic growth ($\ln Y_t$) hypothesis could be tested from Eq. (4), in the next hypothesis: $H_0 = a_{12}{}^1 = a_{12}{}^2 = a_{12}{}^3 = 0$, where $a_{1i's}{}^1$ are the coefficients of the renewable energy variable in the first equation of the system presented in eq. (4). Moreover, we can test the reverse non-causality from economic growth ($\ln Y_t$) to renewable energy consumption ($\ln RE_t$) in the following hypothesis: $H_0 = a_{21}{}^1 = a_{21}{}^2 = a_{21}{}^3 = 0$, where $a_{2i's}{}^1$ are the coefficients of the economic growth variable in the second equation of the system presented in Eq. (4) (Table 6).

Moreover, we can test the reverse non-causality from economic growth ($\ln Y_t$) to renewable energy consumption ($\ln RE_t$) in the following hypothesis: $H_0 = a_{21}{}^1 = a_{21}{}^2 = a_{21}{}^3 = 0$, where $a_{2i's}{}^1$ are the coefficients of the economic growth variable in the second equation of the system presented in Eq. (4).

There are no studies in the literature that investigated renewable energy consumption and GDP linkage for Turkey. But we can compare our results with those of other studies which empirical results suggest conservation hypothesis for Turkey and some other countries. Lee and Chang [30] use panel VARs and the generalized method of moment techniques for the period of 1965–2002 and 1971–2002 respectively, to test the relationships between energy consumption and real GDP in 40 countries. The results suggest that conservation hypothesis for Turkey. Also Lise and Monfort [31] find same results by employing co-integration analysis for Turkey over the period 1970–2003. Tugcu et al. [22] investigates the relationships between renewable energy consumption and economic growth by using Hatemi-J causality tests for the 1980–2009 period in G 7 countries. The estimates suggest conservation hypothesis for Germany. Pao and Fu [24] employed error correction model to test the relationship between GDP and energy consumption for Brazil over the period 1980 to 2010 and the results support conservation hypothesis.

According to Payne [4] country-specific survey results, 29.2% of the neutrality hypothesis, 28.2% of the feedback hypothesis, 23.1% of the growth hypothesis, and 19.5% of the conservation hypothesis are supported. However, other results for lower middle-income and low-income countries supported conservation hypothesis more than the other hypotheses. Our results suggest that the conservation policy of renewable energy consumption will not affect and/or may have a little effect on economic growth. People can use renewable energy in all forms that they need, and in countries like Turkey, which has rich renewable energy sources, this can be a stimulant to economy and economic growth because it meets energy needs at all times; however, one must have investment on transformation devices.

As mentioned above, in Turkey, 70% of the primary energy consumption and 60% of the electricity consumption are

Table 6
Results for causality analysis.

Wald statistic	GDP→RE		Wald statistic	RE→GDP	
	Lag	Causal		Lag	Causal
26.09	1	Yes	0.7539	1	No

dependent on import, so the consumption of local and/or renewable energy sources is very important since Turkey has rich potential for renewable energy sources. Furthermore, recently, global warming which is generated by greenhouse gases emissions is a vital environmental problem for countries. Moreover, energy consumption is a main part of these emissions, so it must be reduced by reducing energy consumption or increasing renewable energy consumption.

The conservation hypothesis is supported by unidirectional Granger-causality running from real GDP to renewable energy consumption. Also this hypothesis suggests that energy conservation and energy demand management policies may not have an adverse impact on economic growth. However, in a developing country, economic growth can be adversely affected by renewable energy consumption due to mismanagement of the energy sources, such as failing to use the rich sources because of energy policies with wrong political and structural applications. In fact, although renewable energy sources are continuous, environment-friendly, and guaranteeing the future of energy, they require significant investment to be used as energy sources, which means that they are expensive investments.

In brief, renewable energy consumption in Turkey should definitely increase both in terms of environmental effects and the abundance of its sources. However, because it is an expensive energy source, it might affect economic growth negatively until the initial investments are made. Indeed, studies reveal that the relationship between energy consumption and economic growth is generally based on conservation hypothesis in poorer countries. For this reason, it might be deduced that this result is normal in this study, which investigated the case in Turkey.

4. Conclusion

Renewable energy source is a very important issue in today's world because it is a clean source of energy and has less negative environmental impact. In addition, countries using these sources will be less dependent on imported fossil fuels. For both consumption and production of renewable energy, all countries must increase their activities.

This study investigates the relationship among renewable energy consumption, capital, labour, and economic growth for Turkey for the period of 1990–2010 using ARDL approach and Toda-Yamamoto causality tests. As mentioned above, it extends the current literature exactly on the causal relationship between renewable energy consumption and economic growth. In the literature, there is no study which has investigated this relationship in Turkey. The empirical test results from the ARDL approach show that renewable energy consumption has a negative impact on economic growth, and ones from Toda-Yamamoto causality tests show that there is a unidirectional causality running from economic growth to renewable energy consumption. In the literature, most of the empirical results suggest feedback or growth hypothesis for developed countries, but this study suggests conservation hypothesis for the relationship between renewable energy consumption and economic growth in Turkey. Renewable energy is an expensive energy source for developing countries, as abundant research studies have revealed that increase in income is a vital supporter behind increased renewable energy consumption. Although this does not mean that energy consumption is not vital for Turkish economy, it could be stated that the role of renewable energy consumption is relatively smaller than the other sources. Also, this result has vital consequences regarding policy, as it suggests that renewable energy limitations do not seem to damage economic growth in Turkey.

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